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Universities, research and brain waste

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Universities, Research and Brain Waste

BY
PROFESSOR J. C. FIELDS, PH.D., F.R.S.

PRESIDENT'S ADDRESS
Royal Canadian Institute
NOVEMBER 8TH, 1919

UNIVERSITY OF TORONTO PRESS
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TRANSACTIONS
OF
THE ROYAL CANADIAN INSTITUTE

UNIVERSITIES, RESEARCH AND BRAIN WASTE

By J. C. Fields, Ph.D., F.R.S.

To the Members of the Royal Canadian Institute

Ladies and Gentlemen:

It is my desire first of all to thank you for the honour which you have conferred on me by electing me your President for the year now beginning. The two years past have been prosperous ones under the Presidency of Dr. J. Murray Clark. Many new members have joined and the attendance at the meetings has appreciably increased. The Institute has carried on its propaganda for research both in regard to its application to industry and on the purely scientific side. In its campaign it has been aided by a succession of eminent lecturers from the United States. The activities of the Institute will continue to be directed by the same policy as hitherto and I may say that arrangements have been made for a group of exceptionally able men to lecture under its auspices in Toronto during the coming winter.

With your permission I shall now turn my attention to the consideration of the subject which I have selected for my address this evening—"Universities, Research and Brain Waste."

Whatever the undeveloped resources of a country may be the greatest of all its resources is the brain of the people and more especially the brain of the exceptionally gifted. Other resources in fact are made available only by combination with this primary resource. The wealth of the race consists of the thoughts of a limited number of men accumulated through the generations. By means of these thoughts, or certain of them, we are able to reproduce things. It takes no great mental effort to realize that of all the material products of man's hands which existed fifty years ago, that which persists to-day is negligible.

There exists a body of men whose function it is to increase the wealth of the race, to add new thoughts to the fund already accumulated. These are the so-called research workers. Men of research inclination there have been in all countries and in all periods. In recent times, however, the number has increased greatly. Certain universities in America, and a large proportion of those in Europe, regard it as one of their functions to prepare men to do research. Many of the European universities regard it as their chief function.

The research workers are makers of modern history as no other body of men are. The difference between the conditions under which our forefathers lived three hundred years ago and those under which we live to-day is due to the research workers. The layman little realizes what an influence individual men among these research workers exercise upon his daily life. In ordinary conversation the name of Shakespeare is heard more frequently than that of Newton and students of the great dramatist will be surprised to be told that Shakespeare as a factor in determining their lives is a bagatelle compared to Newton. The thought of the great scientist, as a matter of fact, permeates our civilization and can be traced distinctly in a multitude of conditions which surround our every-day life. To justify our statement, it suffices to refer briefly to Newton's discoveries of the calculus and the law of gravitation. The calculus is the basis of the greater part of higher mathematical analysis. It is the most powerful of all instruments in handling geometrical problems and it has opened up new territories in geometry which are all its own. What I want more particularly here to refer to, however, is the role which the calculus plays in connection with physical phenomena. Its aid is invoked in questions which relate to motion, light, heat, electricity. The principles of dynamics are formulated in terms of its notation. Unfortunately it has had a share in the development of modern artillery, for the theory of projectiles is an application of the calculus to the law of gravitation. It has had its place in the advances which have brought us the electric light, the trolley, the power house, telegraphy and telephony, both with and without wire. When we read the despatches and cablegrams in our morning paper we do not pause to remind ourselves that the thought of Newton is one of the factors which has made this possible. No more does it occur to the baseball enthusiast that he is under any debt to Newton when he stands before the newspaper office down town and scans the latest baseball bulletin.

Transportation by sea, by land and by air, has much for which to thank Newton. The calculus had nothing to do with the invention of the steam engine by James Watt. It has, however, done important service during the last half century or more in handling problems relating to steam engines and turbines where fundamental principles have been involved. It has had its effect on naval construction. It is involved in the general question of the relation between shape, power and speed in connection with a vessel. It is essential to the study of the strains and stresses in a ship's members. Navigation, too, depends on astronomical data the obtaining of which involves the use of the calculus. Our clocks and watches are regulated by data so obtained. It has had its share in the development of the automobile engine. It proves itself

useful in problems connected with hydraulic elevators. It played a fundamental role in solving the initial difficulties connected with flight, and later on it was an essential instrument in solving the problem of stability in relation to aeroplanes. It renders valuable assistance in connection with the finding of necessary data for the putting up of large steel bridges and for erecting other engineering structures. Physical chemistry makes extensive use of the formulae of the calculus. The physiologist, too, when he is confronted with problems in surface tension is forced to call in its aid.

The same godlike instrument enables the astronomer to follow the earth and the planets in their courses about the sun and to keep track of the moon in its more devious path around the earth as the latter whirls about the sun. It renders it possible for him to measure the combined and varying tugs of the sun and moon on the waters of the earth and with its formulae he traces the paths of the particles of water that go to make up the tides as they travel across the oceans of the earth. By the aid of this instrument applied to the solar system, on the assumption that it is regulated by the law of gravitation, Adams and Leverrier, led thereto by certain inequalities noted in the motion of the planet Uranus, deduced the existence and location of the planet Neptune and foretold its mass and orbit.

Clerk Maxwell it was who formulated the theory of electricity and magnetism in terms of the calculus. Hertz devised the experiment which verified the existence of certain waves in the ether predicted by Maxwell from his theory and Marconi utilized these waves for wireless telegraphy. In later times we have become familiar with X-rays, radio-activity and the theory of electrons. The physicist studies the relative positions of the atoms in a molecule and going beyond distributes the atom itself into electrons. He tells us wonderful stories about the energy locked up in an atom and Sir Oliver Lodge informs us that if this atomic energy were only available a ton of matter day by day would suffice to supply the needs of Great Britain. Going over from the infinitely small to the infinitely great that eminent Dutch astronomer and hardy generalizer, Kapteyn, has launched a scheme to study the structure of the universe. His nearest material is over 25 trillion miles away but his scheme is under way and he is steadily accumulating his data. At some stage in the development of all the branches of physical science here referred to Newton's thought has played a role and the calculus has proved itself a helpful instrument in regions undreamed of by its discoverer.

In what precedes I have touched on the physical sciences and the application of the calculus to them. I have mentioned but a few

among the many great names associated with the development of these sciences. I have wished in a few words to do the impossible, to suggest to the layman by an illustration something of the reach and importance of research, to indicate how the work of one research man connects up with that of another and to shadow forth how intimately the life work of some great thinker may be related to our daily life and activities without our being conscious of the fact. Newton himself, it may be pointed out, was not such an unconditioned being that his work was independent of that of the workers who preceded him. The discovery of the calculus was already a foregone conclusion after Descartes had invented analytical geometry. In the hands of a lesser genius, however, its scope would not have been as fully appreciated and immediate results would have been more meagre. I wish that I could convey briefly to the laymen in my audience some conception of the nature of the calculus but this is not within my power to do. That will perhaps not be surprising in view of the fact that a hundred lectures are devoted to introducing the honours students in mathematics and physics to the subject in their second year and that a considerable portion of their time in their third and fourth years is utilized in increasing their appreciation of its scope and application.

In the foregoing I have said nothing about the immense contributions of chemistry to the health, wealth and comfort of mankind. I have not referred to the debt we owe to biology, botany, bacteriology, geology, and various other branches of science. I have pointed out the successive dependence of one man's work on another's. I would draw attention also to the simultaneous co-operative character of scientific work. For hundreds of research workers in different parts of the world are at the same time busied on the same problems or on related problems. They keep in touch with one another's work principally through highly specialized journals which the layman never sees. In these journals as a rule the results of their investigations are published. To expedite matters it has been found necessary to devise certain aids. One of these is the International Catalogue of Scientific Literature which, before the war, appeared annually in seventeen volumes, each volume corresponding to a separate branch of science. Besides an alphabetical list of authors each volume contains an elaborately classified subject index. This, however, in view of the mass of material being turned out, does not suffice for the needs of the research worker who wants speedy orientation with regard to everything which may have a bearing on his own special line of work. For this something more than a mere classification of titles is needed. Some further indication as to the contents of an article is necessary. The need here referred to is

more or less satisfactorily cared for in different branches of science. In physics and electrical engineering, for example, we have what are called "Science Abstracts".

The need of orientation will be better realized by the layman when he is told that the number of titles listed in the seventeen volumes of the International Catalogue for the year 1912 was 67,926. The great bulk of the literature here referred to is of research character and its authors number up in the tens of thousands. The individuals in this army of investigators vary greatly in ability. Many of them are handicapped by the conditions under which they have to work. The products of their efforts are, of course, very unequal. In the aggregate, however, the importance of the activities of the army of research workers to the welfare of the nations can hardly be overestimated. How many of the nations, how many of the individuals who go to make up the nations, realize this fact? How many of our own people appreciate it adequately?

That does not exist which I do not see is the most prevalent and most disastrous of all fallacies. Every day men in high places act on this fallacy. It shapes important policies and determines great issues. It came very near being the undoing of Great Britain when the opening of the war found her scientifically unprepared, for her statesmen in taking counsel had been accustomed to leaving out of account science which, as it proved, was the most important factor in the situation. It is my own conviction and that of all scientists with whom I have discussed the matter that the modern research movement is the greatest intellectual movement in the history of the human race. How many Governments act as if this conviction had taken hold on them? In how many of the universities on this continent have those in authority seen the vision?

The natural home of research is in the universities. There most of the fundamental discoveries in science have been made in the recent past. Let us hope that this may continue to be the case in the future. The highest functions of a university are on the one hand to provide place and opportunity for the research worker to carry on and make his discoveries and on the other hand to train young men of selected ability to use their creative faculties. This is more fully appreciated in certain European countries than in America.

In Germany, at least before the war, no man was appointed to a university staff who had not proved himself to be intellectually productive. Once appointed he could lecture as little or as much as he pleased. He could devote practically all his time to research if he was so inclined. He was relieved of financial worry. He did not need to preoccupy himself with what, under certain eventualities, would become

of his wife and family. Everything was provided for in advance so that, with a mind at ease, he could concentrate all his powers on his science. On the instructional side the German university had particularly in mind the student of exceptional ability. It put no obstacle in the way of admitting others. It was not a difficult matter to obtain a degree. The arrangements, however, were made with a view to the needs of the more highly gifted. These were trained to be research workers and those who distinguished themselves most in research were the ones who received preferment later on. The intellectually productive men then enjoyed a certain prestige in Germany before the war. This was overshadowed, however, by the factitious prestige attached to the military uniform, and we know how the war-mad militarists of Potsdam prostituted German science and purposed by its aid to subjugate the rest of the world.

In France perhaps more than in any other country is intellectual achievement honoured. An intellectual aristocracy, according to Professor Le Chatelier, is essential to the French democracy. This means that intellect is trained to the service of the State. In peace times membership in one of the five academies which constitute the Institut de France, a purely intellectual distinction, is the highest honour to which a Frenchman can aspire. The Institut, it may be noted, through its Academies disposes of considerable sums as rewards for notable intellectual achievements. The Academie des Sciences in particular has a long list of prizes which are awarded from time to time to scientists who have solved specified problems or who have made advances along certain lines in Science. Living, the creative thinker is regarded as the glory of his country. When he departs this life his remains are buried in the Pantheon with funeral rites which vie with those accorded to a President of the Republic.

In the boy of promise, too, France sees the future man and treats him as a potential asset. He does not need to stop short in his education because his parents are poor. There are bourses awaiting him from the Commune, the Department, and the Government. Where his gifts justify it, he will be provided with the best education which the country can offer. In the advanced classes of certain of the Lycées as many as 75% of the pupils hold bourses. The Government maintains schools of university grade for genius. Entrance to these schools is by competitive examination and the number to be admitted each year is limited. Such schools are the École Normale Supérieure and the École Polytéchnique. In the École Normale literary and scientific studies are both provided for. On the literary side the number admitted annually is limited to 30, on the scientific side to 22. The number of

candidates for admission in science is normally about 150, all young men of exceptional ability. Of these then about 85% are rejected. It is to be noted also that of those accepted many will have made the attempt more than once. Conditions are pretty much the same in regard to the literary candidates. The students at the École Normale follow the lectures at the Sorbonne. They also have special courses of their own, which are sometimes supplementary to those of the Sorbonne. They live in residence, study under direction, have a library at their disposition and work in their own laboratories. After three years in residence, the students are again sifted by examination. The most gifted are directed toward the career of the university professoriate. The others supply a brilliant nucleus for the teaching staffs of the Lycées. Those students whose way has been paid by the Government are under obligation to take service with it for ten years and it in turn is under obligation to furnish them with employment. Half the students at the École Normale are under these conditions.

The number admitted annually to the École Polytéchnique is in the neighbourhood of 200. These would normally constitute about 20% of those who write on the examination for entrance. The course at this great engineering school lasts for two years, after which the student is sent on to the École des Mines, the École Centrale, the École d'Artillerie or some other school for a practical course. Of this school Joffre, Foch, Pétain, Nivelle, and others of the more notable French generals in the war just past are graduates. It was with a certain satisfaction that one learned that a Frenchman had been appointed General-in-Chief of the Allied Armies; for it was practically certain that he would be a graduate of the École Polytéchnique. This would be a sure guarantee of his intellectual calibre, for he would be select among the select. One could rest assured, too, that on top of his course at the École Polytéchnique he would have received an advanced technical training proportioned to his natural ability.

There is a strong mathematical trend to the training given in the École Polytéchnique and it is quite remarkable what a number of famous mathematicians have been turned out by this school. It is hardly necessary to add that graduates of the school whose way has been paid by the Government are under obligation to take service with the Government. The Government, too, finds good use for their services, not alone as officers but also im inportant civil capacities.

The candidate who fails to obtain entrance to the École Normale or the École Polytéchnique may have better success with the École des Mines or the École Centrale, schools also with limited admission. In any case there will be nothing to prevent him hearing lectures at the

Sorbonne, for attendance on the courses given there is not limited as at the other schools I have mentioned.

In England it will shortly be as in France that the boy of exceptional ability will be able to pursue his studies as far as he will however indigent the circumstances of his parents may be. At present there is nothing to prevent him completing his course in the secondary school, for plenty of scholarships to that end are offered by the county councils. There are also more than enough scholarships in classics for entrance to the universities. In science and moderns, however, such scholarships are lacking. The funds to redress the balance here have been promised, so I am told, and it will not be long until arrangements have been made which will provide for carrying the boy of outstanding ability right through the secondary school and the university, or higher technical institution of university grade, and training him for research if his tastes incline that way.

The experience of the Naval Dockyard Schools in England furnishes an interesting commentary on the amount of brain waste there must be in classes of the community where better educational opportunities are not available. The schools here referred to are conducted for the benefit of shipwright apprentices who work in the Dockyards. The apprentices who distinguish themselves in their studies are transferred to the Engineering College at Keyham for a year, and if their showing justifies it, they are then sent on to the Royal Naval College at Greenwich for the three years' course at that Institution.

The majority of the present Constructive Staff at the Admiralty Dockyards were formerly students at the Dockyard Schools. These same schools have furnished a succession of distinguished Directors of Naval Construction at the Admiralty. Among these one might mention Sir William White, the designer of the pre-dreadnoughts, and Sir Phillip Watts, designer of the first dreadnought; others are Sir E. Reed and Sir N. Barnaby. Sir J. Marshall, who started as an apprentice in a Dockyard School, became, later on, Director of the Dockyard. Sir J. Biles, Professor of Naval Architecture at Glasgow, had the same start and this was the case also with Mr. S. J. P. Thearle, formerly Chief Surveyor of Lloyds'. Others could be named who have occupied or who are at present occupying commanding positions with some of the largest private shipbuilding concerns in Great Britain.

What a pity it would have been had such precious material been lost to Great Britain. What a pity it is that so much material of like character has been lost and is being lost to Great Britain and the Empire. What a pity it is, too, that in Canada no adequate effort has been made to salvage equally good material.

The indications are that Great Britain will, in the near future, realize more largely on her latent intellectual resources than she has done in the past. To compete with Germany in technically trained men, however, she will have to increase the flow of students from the secondary schools to the universities and higher technical institutions by every means at her command. Mr. Fisher's education bill will help greatly to that end when it comes completely into force 7 years hence. Under its provisions a pupil who has reached 14 years of age will have the alternative of continuing his studies on full time for 2 years longer or of studying part time until he reaches 18. This will bring him to within sight of entrance to the university. The indications as to who should take a university course ought to stand out fairly definitely by this time and the scholarships referred to above will, no doubt, make their appeal to the ambitious student.

In a recent number of Nature,* Professor R. A. Gregory has given some figures with regard to the relative attendance at Universities in England, Scotland, Wales, Ireland, the United States and Germany, from which a little analysis will draw rather interesting conclusions. The number of university students per ten thousand population is approximately 14 in Germany, 10 in the United States, 5 in England, 17 in Scotland, 7 in Ireland, 6 in Wales. In giving the figure for the United States, Professor Gregory has based it on the 72 universities on the accepted list of the Carnegie Foundation. In Canada, as a whole, the figure would be about 15 and in Ontario it would bulk somewhere in the neighbourhood of 25. Here no account has been taken of the difference in standards for entrance to the universities in different countries or of the difference of age at which the student is prepared to enter. In Germany the average age at which the student leaves the gymnasium is between 20 and 21. In Great Britain the usual age of entrance to a university is between 17 and 18, except in the case of Oxford and Cambridge where it is between 19 and 20. With us the normal age of matriculation is 18 and it is about the same in the United States. Taking these facts into account it will be seen that most of that which passes as university work in Great Britain, Canada, and the United States would be of gymnasial standard in Germany. If we would compare the number of students in the several countries, on the basis of the university standard in Germany, we would probably not be doing injustice to any of the other countries concerned by giving for every 10,000 of population the figures 14 in Germany, 3 in the United States, 3 in England, 6 in Scotland, 3 in Ireland, 2 in Wales, 5 in Canada, 8 in Ontario.

*August 15, 1918.

While in Paris last summer, I found that the total attendance for the year 1913-14 at universities and other educational institutions of university grade in France was in the neighbourhood of 26,000. This is at the rate of a little more than 6 per 10,000 population. It would hardly be necessary to cut this figure down as much as we did with the corresponding figures for the other allied countries. In comparing the university status of France with that of Germany, too, it would only be fair to take account of the selective policy adopted by the former country with regard to the intellectually gifted.

One must not be too hasty in finding implications in the figures we have mentioned or in drawing conclusions from them. They do not imply that the intellectual status of Germany compared with that of England is as 14 to 3, nor do they give the relative positions of the two countries in regard to scientific achievement. The scientific status of a country is determined principally by the quality of the output of its foremost research workers. The status of England in science compared with that of Germany is in the aggregate, no doubt, higher than that given by the ratio 3 to 14. This would seem to indicate that among the scientists trained in England is to be found a larger proportion of high grade ones than is the case with those who are trained in Germany. This may or may not imply a smaller proportionate waste of scientific material among the men of highest intellectual capacity in England than among those who are of a somewhat lower grade. It might imply that the average intellectual level of the classes in England from which the ranks of science are recruited is higher than that of the classes in Germany from which science draws her recruits. My own impression is that the average Englishman has been endowed by nature with more intelligence than the average German. There can be no doubt that the amount of brain power which is undeveloped and which goes to waste in England is something enormous. The one thing that the figures just given do tell us is that in Germany there are more young men in proportion to population who prolong the period of their studies and receive an advanced training than there are in other countries. Of these young men science secures its full share. As a consequence a larger number of highly trained men are available for the purposes of science and industry in Germany than elsewhere. It would appear that men of such training have been spared by Germany during the war as they have not been spared by the Allies.

Two months ago, while in London, England, I had a conversation with Dr. E. C. Worden, chemical expert of the Bureau of Aircraft Production, Washington, D.C., who had been commissioned to report on the chemical factories in the occupied portion of Germany. He had

furnished detailed reports on 62 chemical factories. The largest of these was the factory of the Bayer Company, at Leverkusen, 12 miles from Cologne. At this factory over 3,000 tons of pharmaceuticals, dyestuffs, and other chemicals were awaiting export. The plant is equipped with 3,500 telephones. At the time of Dr. Worden's visit over 500 research chemists were at work, and to these several hundred more would be added as soon as the raw materials were available. According to Dr. Worden Germany kept her technical forces unimpaired by the war. She placed her technical men in positions where they did not run too much risk.

An economic blockade has been divested of some of its terrors for the Germans, for the Haber process has been so improved that they can obtain an ample supply of nitrates from the air. Their agricultural needs in this connection, Dr. Worden states, will be satisfied for all time. At the Badische Anilin und Soda Fabrik, located near Ludwigshafen, above Coblenz, on the Rhine, they are in a position to extract the nitrogen from 2½ cubic miles of air daily. This Company has a new research laboratory which, with its equipment, cost $750,000. In many cases where the Germans used a chemical plant for making explosives, they erected in the neighbourhood a substantial factory on a scale at least equal to that of the plant which was being utilized for war purposes and the factories so erected were all held in readiness to begin operations as soon as the war was over. The expectation was, of course, that these new plants would be paid for by the Allies and no expense therefore was spared in their preparation. It is hardly necessary then to remark that Germany, so far as the chemical industry is concerned, is in splendid condition to resume competition with the other nations of the world.

It evidently behooves the Allies to increase not only their university attendance but more particularly also their output of research workers. This would be advisable under any circumstances. It becomes doubly urgent in the face of a German competition backed by an ample supply of scientifically trained workers. Nowhere is it more necessary to take stock of one's scientific position than it is in Canada.

The figures already given for university attendance do not appear to place Canada in an unfavourable light as compared with countries other than Germany. Gauged by the second set of figures, however, Canada, as a whole, and even Ontario, shows to disadvantage in comparison with Germany. The actual disadvantage, too, is greater than that implied in the ratio of 8 to 14. For the 8 Ontario students would, on the average, be less mature than the 14 German students and would include among them a smaller proportion who are engaged on more

advanced work and preparing to do research. If we limit ourselves to the upper ranges of University work, that is to say to the preparation of research workers, Canada hardly compares with the United States and Ontario itself is quite outclassed by certain States of the Union. It may be remarked, however, that we in Ontario are getting under way.

I have referred to the assistance in the form of scholarships and bourses extended to the poor boys in England and France. We have nothing that corresponds to this in America. Our idea of a scholarship is a comparatively small prize not at all proportionate to the keep of a boy for a year, let alone several years in succession. Our nearest approach to the English conception of a scholarship is what we call a fellowship. This, however, is only available to a graduate student. The attached stipend is usually a meagre one and the fellowship may or may not be renewable for a second or third year. It is often utilized, too, as a pretext for securing a certain amount of cheap teaching.

The fundamental defect in the educational systems on the American continent is the failure to make adequate provision for the training of the exceptionally gifted. It is quite evident that funds must be provided for the care of the mentally defective. A proposition to help those who are backward in their studies will receive a sympathetic hearing. If, however, it were proposed that the State should spend money in establishing a school for genius after the model of one or other of those which are supported by the State in France, the cry of class privilege would be raised. If there were question of extending financial aid in their studies to one or other of two boys, the first of whom was exceptionally gifted, the second of mediocre capacity, and if the man on the street were consulted in the matter, he would more likely than not advise that the money be given to the second boy on the ground that he was already handicapped in competition with the first boy.

With France we should learn to realize that the exceptionally gifted individual is there for the good of the community. All the ameliorations which we enjoy we owe in the last resort to such individuals. The State, then, may well defray the cost of their training for it will ultimately profit more from the expenditure than those on whom the money is expended. One creative worker who adds an increment to the heritage handed down from generation to generation ultimately means more to the nation and the race than a hundred mediocrities trained to their capacity. No number of trained mediocrities could compensate for the loss of a Newton.

Whether America has lost one or more Newtons no one can say for certain. But that many, very many, who should have done creative

work of a very high order have, because of defective educational facilities, failed to achieve their destiny, there can be no doubt. Because of this America in particular and the world in general are so much the poorer.

A generation ago American university conditions were something appalling. In my own department students were everywhere misled. The only way in which one could get an adequate grounding in the calculus was by going to Europe. This subject, which we have already referred to as the basis for most of the higher mathematical analysis, was practically everywhere mistaught. The result was that the potential mathematicians in America were sterilized. One of them, who after his American training had the corrective of a European experience and who now holds an honourable place among American mathematicians, told me ruefully that he would never recover from his early training. I have in mind another and younger man from whom his friends and teachers expected great things. His undergraduate training was of the kind referred to above. On top of it he completed a course in one of the best graduate schools on the continent. He has failed to make good, however. His graduate teachers attribute his failure to the false start given by his undergraduate training. I am inclined to accept this explanation for I know the man and I am convinced that he had the material in him to make a research worker. I have had my own experience in this connection. Fifteen years after I had received my grounding in the calculus I discovered, I am ashamed to say, in a German University, the University of Berlin, that it had been taught to me falsely, irremediably, and fundamentally falsely. A dislocation of fifteen years in one's scientific life can hardly fail to leave its impress.

There are other subjects, I am informed, in which instruction in American universities was almost as bad as that in mathematics a generation ago. Conditions, however, have greatly improved in the interval. A student would be tolerably safe now in accepting the guidance in mathematics offered in any of the larger universities. The like will, no doubt, be true of other subjects also. There is no longer the same urgency as formerly for a student to go abroad. Too much inbreeding, however, is not to be encouraged. A certain amount of circulation is healthful. A university, too, should avoid isolation. It should be in touch with other universities at home and abroad and ought to be familiar with what is going on in the outside world.

The change in conditions in American universities, the improvement in instruction which has taken place during the last twenty-five to thirty years, is due primarily to the initiative and self-sacrifice of hundreds of young men who, from time to time, crossed the Atlantic in pursuit of

knowledge. After years of study abroad these men returned to America with a new outlook and new ideas. They were imbued with the spirit of research and brought it with them into the universities where they received appointments. In the larger institutions there were developments along graduate and research lines. In universities both large and small, the research spirit reacted on the undergraduate work and vitalized it. Bringing a sleepy old text-book routine institution into touch with research has all the effect of connecting a stagnant pool with running water. There are still some pools that would be the better for a little more flow.

The research workers just referred to organized scientific societies. At the meetings of these societies, papers, containing the results of their researches, were read and discussed. Journals were founded for the publication of these papers. The scientific status of the United States and the universities within its borders rose in the eyes of Europe.

The American universities a generation ago were practically all high schools with the exception of the Johns Hopkins University. They are now a combination of university and high school, and in certain of them the research side has been considerably emphasised. The Johns Hopkins was a pioneer in research. It was founded primarily as a research institution. An important feature in its policy was the appointment of big men to its professorships. Big men, however, were not always available. Furthermore it was straitened financially. It did its best under the circumstances and that meant much. Brick and mortar held a small place in its programme and its buildings were less pretentious than those of the larger American universities in general. It established scientific journals and within a few years of its foundation, its prestige in Europe eclipsed that of all other universities on this side of the Atlantic. Other universities supplied with more ample funds have followed the example of the Johns Hopkins and have made research a conspicuous feature of their work. Most universities on this continent might take a lesson from the Johns Hopkins University in regard to the relative emphasis to be laid on men and buildings.

The improvement in the scientific and academic status of American universities during recent years I have attributed primarily to a number of individuals who studied in Europe and brought back with them to America the inspiration of research. To these are to be added scientific graduates of the Johns Hopkins University distributed among the educational institutions of the continent who had their share in leavening the academic sentiment and spreading the research idea. Those who now have charge of research work in American universities and those who are engaged in industrial research on this side of the Atlantic are,

for the most part, pupils of the pioneers in research of whom we have just been speaking.

The research men on the staffs of American universities have done all that is humanly possible for them to do to give efficient instruction in science and to improve research conditions in their institutions. It is up to the university administrators to do their share. Salaries must be increased especially in the junior grades and research men must not be overloaded with teaching. I could mention one of the largest universities on the continent whose policy it has been to pay its professors the minimum for which it could get them. A few years ago the head of a department in this university told me that the professors' salaries there ranged from $2,000 to $5,000 a year. The President was housed palatially. I could point you to another famous institution, known by name to every one in this audience, which has on its list professors who are in receipt of a yearly salary of $2,500 or $3,000. Before the war this institution paid its instructors the princely sum of $900 a year. A few weeks ago I learned that it was now anxious to pay $1,800 for a newly fledged B.A. as instructor in mathematics where it formerly expected to secure a man of Ph.D. grade for half that sum. This is one of the effects of the war. I could name a well-known university where they paid instructors $1,000 a year before the war. Promotion is none too rapid at this institution. Some years ago, so I was told, the head of one of the departments requested the President to increase the salary of one of his instructors to $1,500. The instructor in question was the strongest research man in his department. The President refused the request on the ground that he was not impressive looking. Fortunately, the man in question did not have to wait long for a call elsewhere. He is now professor in another university, where he receives a salary better proportioned to his attainments. An eminent scientist, who was formerly head of a department in an important state university, told me that his two assistant professors, who happened to be married men, were so poorly paid that they had themselves to do their family washing.

That the university administration in America does not always appreciate the efforts of the research man is illustrated in the case of a certain state university which had several men on its staff who were interested in research. These men had published a number of papers in foreign scientific journals. This came to the ears of the Board of Regents. As it happened the Governor of the State was a member of the Board and he lost no time in communicating with the offending professors and informing them that they were hired to teach and not to write. This story I have from a former professor of the university in question.

The administration of a university may not usually express itself in the same way as the State Governor just referred to, but its policy is frequently just as effective in discouraging research. The business administration of an American university when it comes to engaging instructors is apt to apply the law of supply and demand ruthlessly. It takes no account of the motives or ideals of those who are seeking positions on the teaching staff. Among the candidates may be one whose dearest desire in life is to find the opportunity to do research. This privilege he would not forego for anything which fortune or favour could offer him. He has already made his first contributions to knowledge and there is every reason to believe that nature has endowed him with gifts of the highest order. The findings of research appear to him to be the most permanent contribution to our civilization. The great pathfinders in science he regards as the highest product of the race. By identifying himself with science through research it seems to him that he associates himself more closely with the eternal than he can do in any other way. The only opportunity to do research would appear to lie in a university career. The administration offers him a beggarly pittance barely sufficient to hold soul and body together. This he accepts in the expectation that he will find the time for research. Vain delusion! He is loaded down with lectures and tutorial work on the general business principle that the more hours his employers squeeze out of him, the more they are getting for their money. This is the kind of policy which kills the goose that lays the golden egg. The years pass. Possibly our research man gets married. He has no margin to come and go on. Promotion comes slowly. Financial worries multiply. He finds himself at last compelled to abandon his long cherished plans for research. He broods over the futility of his sacrifices and eats his very heart out.

Some there are who are more fortunate, who find it possible to reserve a little time for research and who manage to produce, though under handicap. A few, too, there are who, after years of struggle, arrive in a position where they are masters of the major part of their time and can devote themselves to research, if in the intervening years their productive ardor has not abated.

If then scientific productivity in the American universities to-day is greater than it was a quarter of a century ago the credit therefore is due not to the university administrations, but, as we have already stated, to members of the academic staffs, which members are also responsible for the increased efficiency of scientific instruction in the universities. For the more advanced instruction these men often receive no remuneration. They are permitted as a privilege to undertake this work in addition to their regular work. There is no eight-hour day for the research worker. For overtime he does not receive time and a half pay. He gives the extra time gratis. The layman may think that the scientist is paid for the articles he publishes in the technical journals. This, however, is not the case. He does this work gratis also. The editorial work on the scientific journals is, in general, done without remuneration. I may add furthermore that there is no money in the publication of a scientific treatise or a more advanced text-book.

The man on the street will say any one who does so much work gratis is not practical. There is this side of it, however, that when a man has toiled a lifetime to make a fortune, the very best that he can do with it is to endow research. His benefaction to the race is then of the same effect as that of the research worker. The man of wealth contributes indirectly to the welfare of mankind. He first acquires his wealth and then uses it to subsidize the research worker. The latter makes his contribution directly. Why should we say that he is less practical than the business man who has accumulated wealth? It may be that, under stress of circumstances, he consents to accept less than a decent living salary. The business administration of the university which is willing to take advantage of his position, however, can hardly be called practical for its policy is, in the long run, detrimental to the university, to science and to the best interests of the nation.

In European universities the position of research is less incidental than in the general run of American universities. In Germany the university is essentially a research institution and every member of the teaching staff, as we have already indicated, is appointed on a basis of research qualifications. Practically the same result is secured in France in another way. The professoriate there is recruited from the most select of the select material which is admitted to the schools for genius to which I have already made reference. In certain of the English universities the professorial standard is safeguarded by a system of so-called electors. For those who are not familiar with the system I may say that when a chair becomes vacant a number of men are named whose duty it is to select a man to fill the place. These are known as electors. They are usually men of technical knowledge. Certain of them are from the institution concerned. The others are outsiders. The principal evil the system is intended to guard against is appointment by local pull. The voice of the outsiders, I am told, is usually the determining factor in making the selection. I have in mind a case where there were five electors of whom three were from outside the institution. The two local electors felt under obligation to support a colleague who

was a candidate for the position. The outside electors, however, said that they must have a stronger research man and it was decided in this sense.

In America there are no recognized safeguards for the professoriate such as exist on the other side of the Atlantic. There are no traditional standards by which the candidate for a professor's chair must qualify. It is not always a question of scientific achievement. Local pull is frequently in evidence. Executive and committee work within the university and outside activities with an advertising value often receive their reward. Where, too, it is the intention of the appointing power to make the scientific status of a candidate the determining factor the scientific advice invoked is often far from competent. Some years ago the American Mathematical Society, recognizing the existing state of affairs, named a committee to consider whether it might not be possible to bring the knowledge and experience of the society to bear in the making of mathematical appointments in universities and colleges. The committee, however, reported that they were unable to devise any means for attaining the desired end.

The material which goes to make up the teaching staff of an American university is most heterogeneous. Not all the young men who enter the academic profession are of the idealistic type to which I have referred a little earlier. Their average, however, would compare favourably, I think, with the average in any other walk of life. They all look forward to professorships of course, and one or all may ultimately arrive. Promotion in an American university is slow. The gradations leading up to a professorship are more numerous on this side of the Atlantic than in Europe. Though the scientific qualifications in America are on the whole less exacting than in Europe, advancement, for the man of ability at least, is not as rapid. The man of high attainments will find himself a professor at an earlier age in Europe than in America. However it may be in other departments of human activity America is not the land of the young man in the field of academic work.

I have taken occasion to speak of the overloading of members of the American universities' staffs with teaching. This had reference to the professors in general as well as to the junior members of the staffs. The number of lectures which a professor in an American university is called on to give is much in excess of that demanded of his European compeer. In response to a question of mine as to the number of lectures which he was expected to give in the course of a year, a professor on the staff of Oxford told me that his position required him to lecture 28 hours in the course of the year. As a matter of fact, however, he lectured 56 hours. In France a professor is expected to lecture 3 hours a week. This is

usually for the academic year of 30 weeks though some of the professors in Paris are only required to lecture 15 weeks. In Germany it is stipulated that the professor lecture at least 2 hours a week throughout the academic year. He, usually of his own volition, gives more than the stipulated number of hours. He is not troubled by the limitations of a fixed curriculum, it may be noted. He lectures on subjects of his own choosing and rarely on more than two at a time.

In America it is nothing out of the ordinary for a professor to give from 300 to 500 lectures in the course of a year. The layman may fancy that this is not too much and he is likely enough to jump to the conclusion that the European professor has a very easy time of it. Let us see, however, how it works out. The European professor is in a position to concentrate on one subject at a time. It may be that the literature on the subject is not organized up to date. For the purpose of his course of lectures it will be necessary to organize it. To digest and collate the scattered material is likely enough to be a task of some magnitude. It will probably be as much as he can handle. It may be that it will take him several years to do the work. Here and there, by the way, he may delay over a point which needs to be cleared up or a problem whose solution would be useful. However that may be one result of his labours will, as likely as not, be a treatise which will be of service to many more individuals than he could reach by word of mouth in the class room. These individuals would be located in different countries and distributed over the surface of the civilized earth, including among them seasoned research workers as well as immature students. Occasionally, too, the lectures of a creative thinker will consist largely in the exposition of successive discoveries which he is making in the course of the development of a subject.

The lectures of an American university professor will rarely be of the character of the lectures to which we have just referred. They cannot have such character if they are to run into the hundreds annually. As a matter of fact many of the so-called lectures in universities on this continent consist entirely of text-book work and are purely tutorial in their character. This is necessarily the case in institutions which are half high school and half university.

The typical American professor who lectures on a multiplicity of subjects simultaneously can hardly concentrate on any one of them. He certainly cannot concentrate on all. He has to be perpetually changing interest as he jumps from one subject to another. He has to be content with placing himself in position from day to day with regard to the successive parts of the several subjects, and the position in which he places himself is pretty much the same from one year to another so

that the same lectures are repeated from year to year and finally become a matter of routine.

The lecturer who concentrates on one subject at a time, and changes that subject from year to year or at longer intervals, covers a much larger territory in the end than the man who drives the same half dozen subjects abreast year after year. Besides this he has a much better command over his material. The conditions best adapted to the needs of a scientist, the conditions under which he will attain his maximum as a research worker and prove himself most efficient as a teacher, are not always clearly apprehended by American university administrations.

The American university is administered by a Board of Regents composed wholly or almost wholly of business men. There is a President appointed by the Board and appointments to the teaching staff are made by the Board on the recommendation of the President. In general the Faculty has no representation on the Board and its sole connection with the Board is through the President. There is a good deal of dissatisfaction with this arrangement, I was told while on a visit to the United States last summer. A prominent member of the academic staff of one of the principal American universities gave expression to this feeling by stating that the teaching staff was slave to the administration. There have been some experiments in the way of modifying the organization. Representation of the Faculty on the Board of Regents has been tried. There have also been committees of the Faculty having access to the Board and committees composed of members of the Board and members of the Faculty. With what success these tentatives have met I do not know. There does not seem to be complete unanimity with regard to the remedy which is needed for the existing state of affairs. I may say that in European universities there is no administrative body of the nature of the Board of Regents of an American university and there is no office which corresponds to that of the American university President. The Principal of a British college or university has nothing like the powers of the university President. The Faculty has far more influence in the conduct of affairs than is the case in America. This is in evidence in the making of appointments. For example, where the system of electors is in operation the Faculty has a voice in choosing the electors. It also has its say in the case of universities where the system of electors has not been adopted.

In our Canadian universities we have the American form of administration. Our curriculum and academic standard, however, have been imported from Great Britain. We have adopted the idea of the honours courses, and these courses at the University of Toronto are probably

the heaviest undergraduate courses on the continent. With this foundation one would have said that we should have developed along graduate lines more rapidly than has been the case. Some of the American universities, however, have greatly outdistanced us in the development of graduate and research work. Let us hope that we shall overtake them. Our students who have received their bachelor's degree in one of the honours courses compare more than favourably as a rule with those who have completed an undergraduate course in the corresponding department of an American university. The result of a comparison with the best product of the universities on the other side of the Atlantic is, however, not so favourable. The conception of a university at its best is on a somewhat higher plane in Europe than in America. The same is true also of the secondary school. A young man of exceptional ability being trained in Europe is likely to be somewhat in advance of where he would find himself at the same age if he were being trained in America. On entering Oxford or Cambridge a student specializing in mathematics is about two years ahead of a student entering the University of Toronto in the same department, while he is just one year older. The discrepancy in classics is quite as great. This does not hold in the case of the natural sciences which receive less attention than mathematics and classics in the Public Schools of England. From what we have just said, however, it would appear that it should be possible to so modify the methods of instruction in our Canadian secondary schools as to save a year to our brighter boys by the time they are ready to matriculate. A comparison with results obtained on the continent would lead to the same conclusion.

The university attendance in the Province of Ontario in proportion to population compares favourably with that of any other country except Germany, after all due allowance has been made for inequality of university standards in different countries. Nevertheless 6 out of 7 pupils who pass the High School entrance examination never matriculate. About 7 out of 9 do not attempt the matriculation examination.* Among these boys and girls there are sure to be many who would profit by a university course. Much good material must here go to waste. Why should we not have in Ontario, or better still throughout Canada, a system of scholarships which would provide the highest possible education for the exceptionally gifted? Australia makes such provision for her gifted boys and girls. Why should we do less for ours?

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*The figures here given are based on the results for the matriculation examinations during the five years 1910-14, and on the results for the High School entrance examinations during the five years 1906-1910.

The waste of brain in this world is a tragedy of the first order. There is none greater. This was brought home to us with peculiar emphasis during the war. When Moseley was killed at Gallipoli scientists everywhere felt a sharp pang. Here was a young man who had crossed the threshold. He had just had time to prove his genius. Almost at his first attempt he left his imprint on the science of physics and great things were expected of him. His sudden cutting off did a great violence to the sense of the fitness of things in the minds of those who knew what a loss it meant to science. The toll of Trinity College, Cambridge, in the war was in the neighbourhood of 2,000. Of these some had already been productive and others gave great promise. The most gifted of our young men went overseas and many of them will never return. Among the latter were two of gold medallist standing in my own Department. The sacrifice of a young man of exceptional ability seems to accentuate the unreason and injustice of warfare. Why should he not have been permitted to fulfil his natural destiny, to lead an intellectually productive life and perhaps add a permanent increment to the heritage of the race? Yet the same sacrifice of exceptional gifts, the same waste of brain power, is going on regularly in our midst in peace times and we pay no attention to it. What is possible in this regard I have illustrated by the history of mathematics in America. Successive generations of potential mathematicians were wiped out. They never knew what struck them. Their contemporaries never knew that nature intended them to be mathematicians. The story of the Dockyard Schools is full of suggestion as to the waste that must be going on. We pause to think when we hear of a man like George Green, who was discovered at 40, graduated at Cambridge at 44, and died at 48, after leaving his permanent mark on the history of mathematics and physics. It is said that his later years were saddened by the realization of the fact that the greater part of his life had been wasted. How many George Greens are there who die before 40? How many who are not discovered before 48?

There is no general formula which will enable us to avoid all waste of brain but we should endeavour in every possible way to salvage all we can. It would, no doubt, be helpful to have the advantages of a university or higher technical education presented from different viewpoints to the pupils in the secondary schools, preferably by visiting lecturers. Their studies, too, should include something of a biographical or narrative character touching on the lives and work of the great scientists. This might even with advantage be introduced into the elementary schools. Matter could readily be selected which would not be lacking in romance.

Some adequate reference it seems to me should be made to science in the teaching of history in the schools. Modern history, as I understand it, is an account of how a people, starting out under certain conditions at a given time in the past, have arrived at where they now find themselves. The most important agent involved in the transition, the largest factor by far concerned in modifying the conditions of living during the past two centuries, has been science. Is it not of the first importance that every boy and girl should be made aware of this fact?

By stimulating the interest of the pupils of the preparatory schools in science, by visualizing university opportunities and by establishing a system of scholarships such as we have already referred to, we could doubtless increase considerably the number of students of ability in our universities. Those who do not go to the university, but leave the elementary or secondary school to earn their living, would at least carry away with them a certain respect for science and a recognition of the fact that the university has a useful function to perform in the life of the community. This would later on have its effect in helping to create a public opinion which would react more favourably to proposals for financial aid to universities and science.

A university should be sufficiently staffed to care for the needs of its students. Our own University is undermanned. The tutorial classes should be smaller. This is no good reason, however, why the members of the staff should be overworked. Junior instructors, who have research inclinations, should be given a chance to show the mettle that is in them. The more mature men, who have already proved themselves, should be given time for research. Only yesterday I was talking to a member of the staff who told me that for three weeks past he had been working till three in the morning and that for seven days in the week. The man in question is a research worker, but the work referred to had nothing to do with research. This is, of course, exceptional and it will not ordinarily be necessary for my colleague to work so strenuously. Even so it is a little inconvenient. The same man, too worked till midnight daily during the last month of the vacation getting the materials required in his laboratory in readiness for the opening of the term. I asked him whether he received any pay for work overtime. His reply was an incredulous smile which, interpreted, meant how could any member of a university staff be so ingenuous as to ask such a question.

The case I have cited is an extreme one to be sure. There are plenty of members of the university staff, however, who have more than enough to do and there is none who has not enough to keep him busy. Of this the layman can rest assured. Further staff, of course,

would mean more expense, but the Province would be well paid for its extra outlay.

There should be a larger number of places for research men in Canada. There should be more positions for them in the universities and more in the industries outside. The University of Toronto has begun to develop along research lines and in the course of time, no doubt, much good Canadian brain power will be salvaged which would otherwise go to waste. The projected Institute for Research at Ottawa will absorb some of the men trained by the University for research. It is to be hoped that the demand from the industries will grow. It might be well also to have such men in charge of the science departments in the high schools and to encourage their research inclinations by furnishing them with adequate laboratory equipment. Something of this sort, I understand, it is proposed to do in England.* This would all tend to conserve Canadian brain for Canada and would check the leakage to the United States and other countries. Of the 15,000 living graduates of the University of Toronto, 1,700 are located in the Republic to the South of us. Between 400 and 500 others are domiciled abroad. McGill's loss to the United States is 1,500 out of 6,700 graduates.

It has been suggested that research professors and research associate professors be appointed in the departments of natural science of the University of Toronto, their duties to consist primarily in the prosecution of research on their own account and in the training of young men of selected ability for research. The aggregate of these research men would be known as the research staff in natural science of the University of Toronto.

To me it appears that the organization of such a group would, in addition to creating greater effectiveness within the university, have a two-fold benefit without. On the one hand it would remind the laymen that there exists a body of men in the world whose business it is to advance knowledge and on the other hand it would impress on them the fact that the University is not an institution whose sole function is to purvey knowledge, but that it has also another and quite as important function, namely to add to knowledge and to train young men in order that they may add to knowledge in their turn.

The war has been wasteful of brain power. It has, however, taught us its value. In the work of reconstruction nothing can be of more importance than conserving and realizing on the brain power of the nation. In this work the universities must play the leading role. If

*A provision in the Education Act enables local authorities to meet the cost of research work of educational value conducted by teachers in the schools.

in our reconstructed country we shall have reduced brain waste to a minimum and increased brain output to a maximum, we shall have raised the greatest of all memorials to our boys who sacrificed themselves in France and Flanders in order that Canada should be saved from determination by Germany. It is for the Canada whose destinies will be determined by Canadians that they fought and died and the Canada that is to be will be their monument. Let us make the monument a great and noble one. May it be worthy of those whom it commemorates.

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